

Endovascular Skills for Trauma and Resuscitative Surgery (ESTARS) course: Curriculum development, content validation, and program assessment

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BACKGROUND:	The management of hemorrhage shock requires support of central aortic pressure including perfusion to the brain and heart as well as measures to control bleeding. Emerging endovascular techniques including resuscitative endovascular balloon occlusion of the aorta serve as potential lifesaving adjuncts in this setting. The Endovascular Skills for Trauma and Resuscitative Surgery (ESTARS) course was developed to provide fundamental endovascular training for trauma surgeons.
METHODS:	ESTARS 2-day course incorporated pretest/posttest examinations, precourse materials, lectures, endovascular and open vascular instruments, Vascular Intervention System Trainer endovascular simulator, and live animal laboratories for training and testing. Curriculum included endovascular techniques for trauma; review of wires, sheaths, and catheters; as well as regional vascular injury management. Animal laboratories integrated arterial access, angiography, coil embolization, resuscitative endovascular balloon occlusion of the aorta, control of iliac artery injury, and vascular shunt placement. Students completed a knowledge test (precourse/postcourse) and a summative skills assessment. The test measured knowledge and judgment in vascular injury management as defined in the course objectives. Vascular Intervention System Trainer and animal laboratory were used for final examinations. Subjective performance was graded by expert observers using a global assessment scale and performance metrics.
RESULTS:	Four pilot ESTARS courses were completed, with four participants each. Knowledge and performance significantly improved after ESTARS. Mean test examination scores increased by 77% to 85%, with a mean change of 9 percentage points [paired $t(15) = 7.82$, $p < 0.0001$]. The test was unidimensional (Cronbach's $\alpha = 0.67$). Technical skill significantly improved for both endovascular simulation and live animal laboratory examinations. All participants passed the live animal laboratory practical examination.
CONCLUSION:	The ESTARS curriculum is effective at teaching a basic set of endovascular skills for resuscitation and hemorrhage control to trauma surgeons. ESTARS was confirmed as a stepwise and hierarchical curriculum demonstrating measurable improvements in performance metrics and should serve as a model for future competency-based structured training in endovascular trauma skills. (<i>J Trauma Acute Care Surg.</i> 2014;76:929–936. Copyright © 2014 by Lippincott Williams & Wilkins)
KEY WORDS:	Endovascular; trauma; hemorrhage; resuscitation; aortic balloon occlusion.

Noncompressible torso hemorrhage (NCTH, defined as hemorrhage from the thorax, solid organ injury, axial torso vessel, or pelvic fracture) is associated with high mortality in trauma.^{1,2} Civilian studies demonstrate that NCTH accounts for 60% to 70% of deaths following otherwise survivable injuries, underscoring the burden of this injury pattern. Similarly, 80% of combat-related deaths occurring in troops with otherwise survivable injuries are secondary to NCTH.^{3–5} Early and effective resuscitation and hemorrhage control in the setting of NCTH have the potential to improve survival following military and civilian trauma.

Vascular injury and its management are an increasingly complex part of trauma care.^{6–11} The rate of vascular injury in

the wars in Afghanistan and Iraq has been shown to be five times that previously reported in combat.¹² As such, the wars have resulted in significant advances in the management of vascular trauma and hemorrhagic shock.¹³ One of the most notable has been the establishment of endovascular capabilities into the combat casualty care paradigm.^{14–16} Implemented early, select catheter-based techniques are associated with decreased morbidity and mortality rates compared with open vascular procedures.¹⁷ A potential adjunct to resuscitation in the setting of shock is resuscitative endovascular balloon occlusion of the aorta (REBOA).^{18–25} This technique provides the physiologic benefit of temporary aortic occlusion without the burden of thoracotomy. While this technique was described in the Korean War, it has yet to be widely evaluated for trauma.²⁶

The ESTARS curriculum was developed as a result of the military's impetus to deliver effective resuscitation and hemorrhage control adjuncts to the commonly deployed general and trauma surgeon. With an objective to close the gap in understanding and the implementation of potentially lifesaving techniques among these surgeons most likely to be caring for patients in shock, an endovascular skills curriculum was developed. The objective of this study was to define a practice-based curriculum, combining didactics, simulation, and live

Submitted: September 13, 2013, Revised: November 4, 2013, Accepted: December 16, 2013.

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DOI: 10.1097/TA.0000000000000164

J Trauma Acute Care Surg
Volume 76, Number 4

Report Documentation Page			Form Approved OMB No. 0704-0188		
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 01 APR 2014		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Endovascular Skills for Trauma and Resuscitative Surgery (ESTARS) course: Curriculum development, content validation, and program assessment				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Villamaria C. Y., Eliason J. L., Napolitano L. M., Stansfield R. B., Spencer J. R., Rasmussen T. E.,				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) United States Army Institute of Surgical Research				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 8	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

tissue components to teach a basic set of vascular and endovascular skills to trauma surgeons. An additional objective was to use qualitative and quantitative measures to evaluate the effectiveness of the curriculum in translating this skill set to a cohort of participants.

PATIENTS AND METHODS

The ESTARS course was developed to meet specific learning objectives (Table 1). Participant goals were to obtain competency in basic endovascular skills used in vascular injury management. After training, learners were expected to (1) demonstrate proficiency in diagnosis, exploration, and control of vascular trauma using endovascular techniques and REBOA; (2) deploy temporary vascular shunts; and (3) repair the vascular injury. The ESTARS course lasted for 2 days and consisted of preinstruction knowledge test, precourse instructional materials (50-page manual) sent to participants before the course, didactic lectures, endovascular simulation, exposure to the endovascular and REBOA instruments, multiple hands-on practice sessions using live swine models and a full assessment regimen (Table 2).

Two initial pilot courses were conducted, each with four learners ($n = 8$). The instruction methods and assessment instruments were evaluated after these improvements were made using feedback from learners, instructors, and third-party observers. Real-time evidence-based modification of the ESTARS curriculum occurred during these initial pilot courses. ESTARS course validation was then assessed in four additional courses using the revised methods (four learners each, $n = 16$); the results of these courses are reported in this study.

The course participants were fellowship-trained trauma/critical care surgeons selected from military and civilian centers. No participants had formal vascular or endovascular surgery training. Funding for this research study supported travel/lodging costs, and no course fee was required.

The instructional portion of the course was composed of didactics focused on vascular injury with an emphasis on vascular access and endovascular techniques. Didactics were coupled with hands-on sessions with endovascular supplies

including wires, catheters, and sheaths. Summary tables were provided to standardize endovascular knowledge for participants, with separate tables prepared for wires, catheters, and sheaths. Other tables provided typical “must have” supplies including REBOA supplies as well as types of agents for angiography and common contrast injection volumes and rates (Tables 3 and 4).

Simulation was performed on a Mentice Vascular Intervention System Trainer (VIST, Evanston, IL). The VIST system is a high-fidelity, endovascular simulator with a haptic interface enabling hands-on procedural training for interventional radiology procedures, cardiac catheterization, neuro-interventional procedures, and other endovascular procedures. Access to the VIST allowed participants the opportunity to become familiar with the endovascular supplies in specific simulated case scenarios. The VIST skills assessment included a standardized set of procedures for diagnostic angiography: thoracic and abdominal aortography, pelvic angiography, and up-and-over technique for selective internal iliac angiography.

Live animal models used for injury simulation were female Sus Scrofa Yorkshire swine (70–90 kg). The animal research protocol (FWH20100190A) was approved by the Institutional Animal Care and Use Committee at the 59th MDW Clinical Research Division Lackland Air Force Base, Texas. Each participant had the opportunity to gain ultrasound-guided percutaneous femoral artery access, with a micropuncture needle on the model followed by upsizing and exchanging of sheaths and the introduction and use of wires and catheters for hemorrhage control. A standardized traumatic injury (iliac artery penetrating injury) was used. Unique to this course are exposure to the use of temporary vascular shunts as well as introduction to basic endovascular techniques for the diagnosis and treatment of vascular trauma including REBOA.

All course sessions were taught by the same two-person team consisting of one board-certified vascular surgeon and one board-certified trauma surgeon. The instructors were knowledgeable in both open and endovascular components of vascular injury management to maintain fidelity of the technical endovascular aspects of the curriculum.

Assessment

Trainees in the ESTARS program were assessed on their domain knowledge before and immediately following training. Trainees’ procedural skills for vascular injury management using open and endovascular techniques were assessed using simulator and live models. Using assessment data from 24 trainees during the course of six training programs, we have developed an assessment standard that can certify that a trainee has demonstrated competence in endovascular and REBOA techniques for trauma and resuscitative surgery.

The knowledge test was delivered and scored electronically using a custom-built Web interface and consisted of 68 items of a mixture of 25 multiple-choice, 26 true/false, and 17 multiple true/false items. The purpose of the test was primarily formative; the same items were used for pretesting and posttesting, and the pretest served as a learning tool focusing learners on the content of importance. Mean scores were computed, treating each item as one point (multiple true/false

TABLE 1. Specific Learning Objectives

After the training course, the learner will be able to
1. Perform ultrasound-guided access of femoral vessels using micropuncture techniques and devices
2. Perform basic fluoroscopy and contrast injection techniques
3. Perform “up-sizing” of initial access device to sheath and platform sizes able to accommodate select endovascular maneuvers
4. Demonstrate use of wires of different sizes and types including degrees of rigidity, hydrophilic nature, and lengths
5. Demonstrate the use of nonselective and selective angiographic catheters including basic configurations and lengths
6. Perform selective arteriography and placement of catheter-direct coil embolization or placement of other hemorrhage control adjuncts
7. Perform REBOA for trauma
8. Perform large sheath removal and arterial injury control (open primary repair or use of temporary vascular shunt)

TABLE 2. ESTARS Course: Vascular and Endovascular Management of Trauma

Day 1	Pretest Computer Examination—Completed Before Course
8:00–8:30 am	Introduction to vascular injury management
8:30–8:45 am	Endovascular techniques for vascular trauma: what is the evidence?
8:45–9:00 am	Endovascular techniques in trauma—history
9:00–9:15 am	Break
9:15–9:35 am	Endovascular techniques—wires/hands-on session with wires
9:35–9:50 am	Endovascular techniques—sheaths/hands-on session with sheaths
9:50–10:10 am	Endovascular techniques—catheters and microcatheters/hands-on session
10:10–10:30 am	Endovascular techniques in trauma—pearls
10:30–10:45 am	Introduction to the VIST endovascular simulator
10:45–11:00 am	Break
Parallel Sessions	
11:00–1:00 pm	VIST endovascular hands-on training (four students, 30 min per student)
	<ul style="list-style-type: none"> • Retrograde transfemoral catheterization of abdominal aorta • Arch aortogram, abdominal aortogram, pelvic angiogram • Selective angiography contralateral iliac artery (up/over)
11:00–1:00 pm	Retrograde transfemoral access with micropuncture kit (with video)
	Hands-on session: shunts, clamps, surgical instruments for vascular injury
	Introduction to porcine anatomy (slides)
1:00–1:30 pm	Lunch
1:30–2:00 pm	Live animal laboratory—bilateral femoral arterial access (1 student per side)
2:00–3:00 pm	Diagnostic aortography—arch aortogram, abdominal, pelvic angiogram
	Selective angiography of renal artery, iliac artery (up/over)
3:00–3:30 pm	Upsize right to 14 Fr Introducer, place aortic occlusion balloon catheter CODA
3:30–4:00 pm	Standard iliac arterial injury, inflate aortic balloon for hemorrhage control
	Open management, proximal/distal arterial control, local heparin, shunt
4:00–4:30 pm	Vascular injury management (didactic)—aortic injury (open vs. endovascular)
4:30–5:00 pm	Vascular injury management (didactic)—pelvis cases and extremity
Day 2	
8:00–8:30 am	Vascular injury management—cervical
8:30–9:00 am	Vascular injury management—abdominal
9:00–9:30 am	Break
9:30–10:00 am	Live animal laboratory—bilateral femoral arterial access (one student per side)
10:00–10:30 am	Selective angiogram of renal artery and bilateral coil embolization of branches (one side per student)
10:30–11:00 pm	Upsize right side to 14 Fr Introducer, place aortic occlusion catheter Berenstein
11:00–11:30 pm	Standard iliac arterial injury, inflate aortic balloon, place vascular shunt (switch student roles from live animal laboratory Day 1)
11:30–12:00 pm	Lunch
12:00–2:00 pm	Live injury animal laboratory practical examination (two students)
	VIST simulator practical examination (two students)
	Posttest computer examination (done while waiting for other examinations)
2:00–3:00 pm	Debrief and questions

responses were scaled with false-positive and false-negative responses treated as 0 point and all correct responses summing to a maximum of 1 point for the entire item).

Trainees performed three tasks on the VIST simulator with guidance from an instructor who also rated the performance, made notes, and completed a standardized task simulator checklist (SC). Simulator objective measures (SOMs) were obtained from the simulator software and were analyzed to assess learners' normative performance standards for speed and accuracy. The Global Ratings Scale (GRS) was a seven-item form that rated learner's overall performance quality at

a high subjective level. Raters completed each item using a 5-point anchored scale.

Statistical Analysis

Assessment measures were tested for unidimensionality using Cronbach's α . When appropriate, normality was tested using Shapiro-Wilk's W , and means and SDs were examined for acceptably normally distributed measures. Pretest and posttest results were compared using repeated measures (paired t test). Measures were additionally tested for cohort effects by including pilot number as a categorical predictor variable.

TABLE 3. Typical Aortogram Contrast Injection Volume and Rates

Study	Total Contrast Volume and Rate	Contrast Volume and Rate	Appropriate Catheter	Position and Optimal Screen View
Aortic arch	20–35 mL/s for a total volume of 40–70 mL with high frame rate (six frames per second)	“20 for 40”—20 mL/s for a total volume of 40 mL of full-strength contrast for arch	Usually through a 5 or 6 Fr flush catheter Needs full strength contrast CO ₂ contraindicated for arch aortogram	Steep left anterior oblique (LAO) to see “best curve” for the transverse aortic arch
Abdominal aorta	15–20 mL/s for a total volume of 30–40 mL (4–6 frames per second)	“15 for 30”—15 mL/s for a total volume of 30 mL of full-strength contrast for abdominal aorta	Usually through a 5 or 4 Fr flush catheter	Catheter at the top of the screen positioned at T12 to L1 15 to 20 degrees LAO
Pelvic angiogram (injecting at terminal aorta)	8–12 mL/s for a total of 20–30 mL (2–6 frames per second)	“10 for 20”—10 mL/s for a total volume of 20 mL of full-strength contrast for pelvic angiogram	Usually through a 5 or 4 Fr flush catheter	Top of the pelvis to include femoral heads, anteroposterior projection, or right anterior oblique and LAO projections at approximately 30 degrees (contralateral oblique, i.e., right anterior oblique for left side) for complete.

Larger models were tested using univariate general linear models with random effects reduced using iterative restricted estimated maximum likelihood. Analyses were conducted using R version 2.11.1 (<http://www.r-project.org/>) JMP Pro 10 (SAS Institute Inc., Cary, NC, USA) for Macintosh.

RESULTS

Learners

There were a total of 8 participants (trauma surgeons) in the two initial pilot courses. There were an additional 16 trauma surgeons in the course validation group. Trauma surgeons were from various institutions and with varying degrees of experience. Only 1 learner of the 16 did not receive a “pass” rating from the instructors. All other learners were deemed to have demonstrated proficiency in the target techniques and met the stated learning objectives. There was a performance checklist for the animal model task. We evaluated live animal model performance, and all participants completed the task, but summarizing the qualitative nature of the assessment is beyond the scope of this article.

Knowledge Test (Pretest and Posttest)

The knowledge test was acceptably unidimensional with a Cronbach's $\alpha = 0.67$ indicating that the total score on the test is a good indicator of the construct being measured. Total

scores across pretraining and posttraining administrations ranged from 69% to 90% correct and were clearly bimodal (although not enough to statistically reject normality: Shapiro-Wilk $W = 0.95$, $p > 0.05$). Trainee's knowledge test performance increased after training: posttest scores (mean, 85%; SD, 4 percentage points) were higher than pretest scores (mean, 77%; SD, 4 percentage points) (Welch $t_{29,6} = 6.09$, $p < 0.0001$), and paired t tests by learner were even stronger: the mean increase of 9 percentage points was significant with $t_{15} = 7.82$ ($p < 0.0001$, Fig. 1).

Learner improvement did not seem to be caused by any particular pilot session either because of better participants or a better effect of learning in that particular session. A general linear model of total score by participant (as a random factor) and pilot, timepoint (pre- vs. post-) and a pilot-by-timepoint interaction found only an effect of timepoint [$F(1,12) = 13.92$, $p < .005$] but neither pilot [$F(3,12) = 0.40$, nonsignificant] nor the interaction [$F(3,12) = 0.75$, nonsignificant]. These data are consistent with a training program that is reliably successful at improving trainee's knowledge as measured by the test.

GRS for Live Animal Laboratory

The scale demonstrated high internal consistency (Cronbach's $\alpha = 0.89$), suggesting that the items all target a common level of quality. No trainees received a rating less than

TABLE 4. Typical “Must Have” Trauma Endovascular Diagnostic/Treatment Inventory

Arterial Access	Wires	Sheaths	Catheters	REBOA
Micropuncture kit 21 gauge needle 4 Fr or 5 Fr catheter 0.018-in guide wire	0.035 in starter J 180-cm wire (Boston Scientific)	Pinnacle 4 Fr 10-cm sheath (Terumo)	100-cm 5 Fr Pigtail Catheter (Cook)	CODA Balloon 14 Fr (32-mm diameter, 120-cm length) Cook Medical
Single-wall puncture needle, 19 gauge	0.035-in Rosen 180-cm wire (Cook) 0.035 in Floppy angled glidewire 180 cm (Terumo)	Pinnacle 5 Fr 10-cm sheath (Terumo) Pinnacle 6 Fr 10-cm sheath (Terumo) Pinnacle Destination 6 Fr 45-cm sheath (Terumo)	65-cm 5 Fr C2 Cobra Glide Catheter (Terumo) 100-cm 5 Fr Angled Glide catheter (Terumo) 65-cm 5 Fr SOS Omni catheter (Angiodynamics)	14 Fr Introducer sheath Amplatz guide wire (0.035 in)

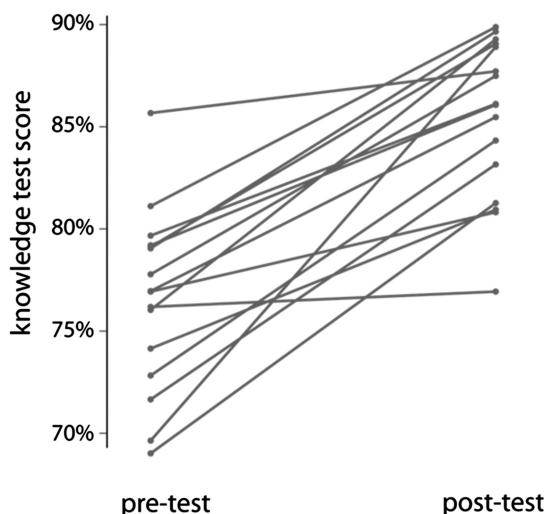


Figure 1. Course participant knowledge assessed by pretest and posttest examination scores.

3 on any item, suggesting that the scale should be reworked to improve sensitivity to differences in trainee skills. The high internal consistency suggests measurement redundancy and a possibility to shorten the instrument. “Respect for tissue” and “Instrument handling” for instance were highly correlated ($r = 0.91$), indicating that they measure the same construct. The “flow of operation and forward planning” item correlated most highly with the overall rating, suggesting that it is measuring the subjectively most important construct to the rater.

SOM and SC

The SOMs were composed of two reliable factors as follows: exploration efficiency (total time on the simulator, total time using fluoroscopy, total amount of contrast used, number of cines, total cine time, and time per cine) and cine efficiency (number of cines and average time per cine). Together, these factors explained 62% of the performance data. To compute these subscores directly, the number of cines was dropped owing to being somewhat intermediate between the factors and informationally redundant with the average time per cine. The subscores are then computed as the mean of total fluoroscopy time and total contrast time (an exploration efficiency score measured in seconds; lower is better) and time per cine (a cine efficiency score measured in seconds; lower is better).

Performer technical skill significantly improved for endovascular simulation as measured by VIST performance metrics. Participants spent a mean of 17:58 minutes on the entire task, which consisted of recording four cine loops. Procedure times ranged from 11 minutes 6 seconds to 27 minutes 57 seconds.

As is common with duration measures, the SOM subscores fit a log-normal distribution. The 90% point of the log-normal curves for exploration efficiency (mean [SD], 326.6 [115.9] seconds) and cine efficiency (mean [SD], 6.5 [2.8] seconds) were 506 seconds and 12 seconds, respectively: these points would likely make appropriate “red flag” cutoff points to

indicate learners who overuse fluoroscopy and contrast (exploration efficiency) or cine time (cine efficiency). The SC did not show enough variance to be quantitatively interesting: no learner scored lower than 95% on the checklist, with 100% being the modal score.

Relationship Between Measures

The exploration efficiency subscore from the SOM correlated negatively with “respect for tissue” and “time and motion” ratings on the GRS. The cine efficiency subscore correlated negatively with “flow of operation and forward planning” ratings on the GRS. While neither of these correlations were statistically significant, they were in the predicted direction; a larger sample might find statistical significance.

DISCUSSION

This report demonstrates that the ESTARS curriculum is effective in conferring a basic set of endovascular catheter-based skills to trauma surgeons with limited previous exposure to such techniques (during general surgery or trauma surgery training). With the use of the ESTARS curriculum, more than 90% of learners demonstrate aptitude in the defined skill set including arterial access, exchange of sheaths, wires, and catheters and the performance of urgent REBOA. The ESTARS curriculum provides a foundation for military and civilian efforts to translate potentially lifesaving resuscitation and hemorrhage control maneuvers to those most likely to provide acute care for injured patients in hemorrhagic shock. Importantly, some trauma surgeons who completed this course were successful in appropriate clinical application.²⁷

Origins of ESTARS

The utility of endovascular maneuvers for select patterns of bleeding has been recognized for decades. However, until recently, these have been mostly used by radiologists or nontrauma surgeons for age-related disease processes. The unprecedented burden of injury during wars in Afghanistan and Iraq has spurred a reappraisal of the effectiveness of endovascular maneuvers. Foremost, the wars have laid bare the imperative to more effectively manage bleeding, specifically shock from NCTH. Also fueling this reappraisal has been the deployment of vascular and endovascular surgeons into a sustained period combat casualty care. In this setting, these surgeons have worked next to general and trauma surgeons unencumbered by practice, referral, and financial factors. In this context, traditional “silos” separating trauma surgeons from endovascular surgeons have been broken down. A final transformative factor has been the revolution in endovascular technologies. Devices are now lower profile, less complicated, and more amenable to use by skilled emergency surgeons. In this milieu, the military’s Combat Casualty Care Research Program in partnership with the University of Michigan developed the ESTARS curriculum to spur translation of potentially lifesaving skills to providers most likely to provide acute care for patients in shock.

Measurement of Proficiency and Knowledge

In this curriculum, proficiency seemed best assessed by both objective (i.e., timing of simulator performance) and

subjective (i.e., global assessment of performance in live animal laboratory by trainers) measures. As predicted by the learning objectives, exploration efficiency and cine efficiency were dissociable from the performance measures, suggesting that exploration and injury control are independent skills. This insight could be used to focus the training more clearly on each of these skills, perhaps improving its effectiveness. The knowledge test seemed most useful as a formative exercise, with the pretest helping learners approach the didactic sessions with an understanding of the primary learning objectives. The increase in performance from pretest to posttest is to be expected since the content of the test and the didactic sessions were designed in parallel.

Combined Live Tissue and Simulator Training Models

The ESTARS course and the current study aligned with the premise that a combination of live animal and simulator training would be best to acquire and maintain endovascular skills. Courses such as the Advanced Surgical Skills for Exposure in Trauma (ASSET),²⁸ Trauma Exposure Course (TEC),²⁹ or Advanced Trauma Operative Management (ATOM)³⁰ are based on this premise and have provided surgeons of various specialties a platform to perform procedures competently. Although based on a similar foundation, ESTARS is unique as it is the first to emphasize the use of endovascular methods for resuscitation and hemorrhage control in a model of hemorrhage and shock.

Emerging “Hands-on” Training Experiences

As an indication of the paradigm shift to translate endovascular skills to trauma surgeons and emergency providers, other “hands-on” experiences are being developed. The Basic Endovascular Skills for Trauma program is being implemented by investigators at The R. Adams Cowley Shock Trauma Center in Baltimore. This innovative and concise 2-hour curriculum consists of didactics and hands-on experience with sheathes, wires, and balloons using an endovascular simulator. This curriculum is portable, easily repeated, and focused only on familiarizing participants with skills to perform REBOA. As this course matures, it is likely to incorporate novel models of pressurized cadaveric vasculature including the aorta and iliofemoral segments. Similar mini courses or focused experiences using simulators and cadavers are being implemented at the Memorial Herman Medical Center at the Texas Trauma Institute in Houston and other centers around the country (personal communications).

Internationally, the Diagnostic and Interventional Radiology in Emergency, Critical care, and Trauma (DIRECT) course has been developed in Japan by Matsumoto and colleagues. DIRECT is a 1-day course consisting of didactic sessions and hands-on experience with simulators, embolization materials, and computer/computed tomography–assisted software. Participants in the DIRECT course include emergency medicine physicians, interventional radiologists, and trauma surgeons. The development of other experiences and courses underscore the common desire to translate a basic endovascular skill set to providers who are best positioned to use them in the acute setting. However, it is important to note

that ESTARS has taken steps to control for factors that may confound the translation of skills and developed a standardized and validated curriculum. In this context, ESTARS may serve as one standard by which to compare distinct and or complementary courses as they are developed.

Limitations

Inclusion of only trauma surgeons as participants in this study may have introduced a bias impacting the reported efficacy of this curriculum. Specifically, this cohort of surgeons entered the course with baseline training and experience, which may have elevated the precourse examination results compared with what would have been found with less experienced participants. In this context, this study may have misrepresented the full utility of this curriculum to translate endovascular skills to nontrauma surgeons or emergency providers. We did not examine the relationship between course performance and years of experience because these data were not collected in this study. An additional limitation pertains to this study failing to address actual clinical use and retention of the skills taught by the course. It is not yet possible to determine how frequently these skills might be used by the average trauma surgeon, and it may differ greatly in different institutions. Additional studies will be required to assess this. Despite these limitations, the ESTARS provides a foundation from which to teach providers and to eventually assess longer-term use and retention of the skill set.

CONCLUSION

The ESTARS course is a stepwise and hierarchical training curriculum effective at translating basic endovascular skills to trauma surgeons. The curriculum is the first to optimize endovascular training for surgeons using both an endovascular simulator and a standardized, animal model of hemorrhagic shock. The ESTARS course accomplished improvements in performance metrics pertaining to endovascular procedures used for resuscitation and hemorrhage control and should serve as a model for competency-based structured training in endovascular trauma skills.

AUTHORSHIP

J.L.E., L.M.N., R.B.S., J.R.S., and T.E.R. contributed to the design of this study. All authors participated in the data collection, analysis, and writing. C.Y.V., J.L.E., L.M.N., R.B.S., and T.E.R. critically revised the final manuscript.

DISCLOSURE

This study was funded by the Department of Defense Award F029024-Vascular Injury Advanced Training.

REFERENCES

1. Morrison JJ, Rasmussen TE. Noncompressible torso hemorrhage: a review with contemporary definitions and management strategies. *Surg Clin N Am*. 2012;92:843–858.
2. Kisat M, Morrison JJ, Hashmi ZG, Efron DT, Rasmussen TE, Haider AH. Epidemiology and outcomes of non-compressible torso hemorrhage. *J Surg Res*. 2013;184:414–421.

3. Stannard A, Morrison JJ, Scott DJ, Ivatury RA, Ross JD, Rasmussen TE. The epidemiology of noncompressible torso hemorrhage in the wars in Iraq and Afghanistan. *J Trauma Acute Care Surg*. 2013;74(3):830–834.
4. Holcomb J, Caruso J, McMullin N, Wade CE, Pearse L, Oetjen-Gerdes L, Champion HR, Lawnick M, Farr W, Rodriguez S, et al. Causes of death in US Special Operations forces in the global war on terrorism: 2001–2004. *Ann Surg*. 2007;245(6):986–991.
5. Eastridge BJ, Mabry RL, Seguin P, Cantrell J, Tops T, Uribe P, Mallett O, Zubko T, Oetjen-Gerdes L, Rasmussen TE, et al. Death on the battlefield (2001–2011): implications for the future of combat casualty care. *J Trauma Acute Care Surg*. 2012;73(6 Suppl 5):S431–S437.
6. Rasmussen TE, Woodson J, Rich NM, Mattox KL. Current opinion: vascular trauma at a crossroads. *J Trauma*. 2011;70(5):1291–1293.
7. Burkhardt GE, Rasmussen TE, Propper BW, Lopez PL, Gifford SM, Clouse WD. A national survey of evolving management patterns for vascular injury. *J Surg Ed*. 2009;66(5):239–247.
8. Kauvar DS, Lefering R, Wade CE. Impact of hemorrhage on trauma outcome: an overview of epidemiology, clinical presentations, and therapeutic considerations. *J Trauma*. 2006;60(Suppl 6):S3–S11.
9. Kauvar DS, Wade CE. The epidemiology and modern management of traumatic hemorrhage: US and international perspectives. *Crit Care*. 2005;9(5):S1–S9.
10. Martin M, Oh J, Currier H, Tai N, Beekley A, Eckert M, Holcomb J. An analysis of in-hospital deaths at a modern combat support hospital. *J Trauma*. 2009;66(4):S51.
11. Kelly JF, Ritenour AE, McLaughlin DF, Bagg KA, Apodaca AN, Mallak CT, Pearse L, Lawnick MM, Champion HR, Wade CE, et al. Injury severity and causes of death from Operation Iraqi Freedom and Operation Enduring Freedom: 2003–2004 versus 2006. *J Trauma*. 2008;64(2):11–15.
12. White JM, Stannard A, Burkhardt GE, Eastridge BJ, Blackburne LH, Rasmussen TE. The epidemiology of vascular injury in the wars in Iraq and Afghanistan. *Ann Surg*. 2011;253(6):1184–1189.
13. Markov NP, DuBose JJ, Scott D, Propper BW, Clouse WD, Thompson B, Blackburne LH, Rasmussen TE. Anatomic distribution and mortality of arterial injury in the wars in Afghanistan and Iraq with comparison to a civilian benchmark. *J Vasc Surg*. 2012;56(3):728–736.
14. Rasmussen TE, Clouse WD, Peck MA, Bowser AN, Eliason JL, Cox MW, Woodward EB, Jones WT, Jenkins DH. The development and implementation of endovascular capabilities in wartime. *J Trauma*. 2008;64:1169–1176.
15. Propper BW, Alley JB, Gifford SM, Burkhardt GE, Rasmussen TE. Endovascular treatment of a blunt aortic injury in Iraq: extension of innovative endovascular capabilities to the modern battlefield. *Ann Vasc Surg*. 2009;23:19–22.
16. Arthurs ZM, Sohn VY, Starnes BW. Vascular trauma: endovascular management and techniques. *Surg Clin N Am*. 2007;87:1179–1192.
17. Avery LE, Stahlfeldt KR, Corcos AC, Scifres AM, Ziembicki JA, Varcelotti J, Peitzman AB, Billiar TR, Sperry JL. Evolving role of endovascular techniques for traumatic vascular injury: a changing landscape? *J Trauma Acute Care Surg*. 2012;72(1):41–46; discussion 46–47.
18. Edwards WS, Salter PP Jr, Carnaggio VA. Intraluminal aortic occlusion as a possible mechanism for controlling massive intra-abdominal hemorrhage. *Surg Forum*. 1953;4:496–499.
19. Stannard A, Eliason JE, Rasmussen TE. Resuscitative endovascular balloon occlusion of the aorta (REBOA) as an adjunct for hemorrhagic shock. *J Trauma*. 2011;71(6):1869–1872.
20. Markov NP, Percival TJ, Morrison JJ, Ross JD, Scott DJ, Spencer JR, Rasmussen TE. Physiologic tolerance of descending thoracic aortic balloon occlusion in a swine model of hemorrhagic shock. *Surgery*. 2013;153(6):848–856.
21. Scott DJ, Eliason JL, Villamaria C, Morrison JJ, Houston R 4th, Spencer JR, Rasmussen TE. A novel fluoroscopy-free, resuscitative endovascular aortic balloon occlusion system in a model of hemorrhagic shock. *J Trauma Acute Care Surg*. 2013;75(1):122–128.
22. Morrison JJ, Percival TJ, Markov NP, Villamaria C, Scott DJ, Saches KA, Spencer JR, Rasmussen TE. Aortic balloon occlusion is effective in controlling pelvic hemorrhage. *J Surg Res*. 2012;177(2):341–347.
23. Martinelli T, Thony F, Declety P, Sengel C, Broux C, Tonetti J, Payen JF, Ferretti G. Intra-aortic balloon occlusion to salvage patients with life-threatening hemorrhagic shocks from pelvic fractures. *J Trauma*. 2010;68:942–948.
24. Abu-Zidan FM. Should intra-aortic balloon occlusion be used to stop bleeding from severe pelvic fractures? *J Trauma*. 2010;69:1005–1006; author reply 1006–1007.
25. White JM, Cannon JW, Stannard A, Markov NP, Spencer JR, Rasmussen TE. Endovascular balloon occlusion of the aorta is superior to resuscitative thoracotomy with aortic clamping in a porcine model of hemorrhagic shock. *Surgery*. 2011;150:400–409.
26. Hughes CW. Use of an intra-aortic balloon catheter tamponade for controlling intraabdominal hemorrhage in man. *Surgery*. 1954;36(1):65–68.
27. Brenner ML, Moore LJ, Dubose JJ, Tyson GH, McNutt MK, Albarado RP, Holcomb JB, Scalea TM, Rasmussen TE. A clinical series of resuscitative endovascular balloon occlusion of the aorta for hemorrhage control and resuscitation. *J Trauma Acute Care Surg*. 2013;75(3):506–511.
28. Ali J, Sorvari DH, Luchette F, Bowyer M. Potential role of Advanced Surgical Skills for Exposure in Trauma (ASSET) course in Canada. *J Trauma*. 2011;71:1491–1493.
29. Gunst M, O’Keeffe T, Hollett L, Hamill M, Gentilello LM, Frankel H, Shafi S. Trauma operative skills in the era of nonoperative management: the trauma exposure course (TEC). *J Trauma*. 2009;67:1091–1096.
30. Jacobs LM, Burns KJ, Kaban JM, Gross RI, Cortes V, Brautigam RT, Perdrizet GA, Besman A, Kirton O. Development and evaluation of the advanced trauma operative management course. *J Trauma*. 2003;55:471–479.

DISCUSSION

Dr. Steven R. Shackford (San Diego, California): I want to thank Dr. Villamaria for sending me this manuscript well in advance of the meeting. Dr. Villamaria, I want to thank you for your service.

I just want to say at the outset that I am a card-carrying vascular surgeon and I received my endovascular training at a two-day course, but all of my endoluminal cases are done with my colleagues in interventional radiology. Here are my questions:

First, how were the initial 16 trauma surgeon students selected to take this course? Was it random selection by the authors or did the students self-select? Did they have to pay for the two-day course? These questions relate to their potential motivation to do well.

Second, what was the experience level of the trauma surgeons who took the course? In the manuscript you mentioned in the discussion that they had “minimal or no previous exposure to these techniques.” What, exactly, does “minimal” exposure mean? This has to do with their ultimate performance.

Third, we would all agree that hemorrhagic shock is a problem, but preventable death due to hemorrhagic shock is becoming less and less of a problem in the civilian sector with the development of systems and with the lessons that we have learned from the military with respect to damage control resuscitation and damage control surgery.

Fourth, you cite Dr. Rasmussen’s paper describing people dying in the field who don’t have access to this type of skill. In point of fact, the problem of non-compressible hemorrhage in the military has been somewhat reduced with improvements in body armor, now with groin flaps. In fact, Dr. Rasmussen and his colleagues in their most recent article discussing the epidemiology of non-compressive torso hemorrhage describe a total of only 331 casualties reaching medical help of over 15,000 who actually had non-compressible torso injury producing shock in over eight years—an incidence of only about 2% or about one per week and only 41 had major vascular injury or

5 per year. The others had ruptured livers, ruptured spleens and so forth, about which REBOA may or may not be helpful. Is it worth training surgeons to use endovascular skills when they are so infrequently needed and when resuscitative thoracotomy, in your own experimental study, may be equally effective in occluding the aorta and improving cardiac and brain blood flow?

Fifth, utilizing many of the skills outlined in the course, such as selective pelvic arteriography, will require imaging and a catheter inventory, which are usually associated with having an IR team who do these procedures several times daily at a busy center. Why would we compete with those skills? Why not just leave it at placement of an aortic balloon in the rare cases that need them?

Finally, regarding the imaging inventory, Dr. Rasmussen in his article described the implementation of endovascular capabilities in war time, states: "The majority of 30 patients in whom angiography led to open surgical repair were best served with this operative course because of the injury pattern and surgeon discretion. There were a small number of patients during this study period in whom an endovascular option may have been preferable but was not attempted because of lack of inventory or imaging capability."

Do the authors perceive that these endovascular skills will be used in the resuscitation bay and will the inventory and imaging capability be satisfactory?

Dr. Matthew J. Wall (Houston, Texas): I enjoyed your presentation and this is important. Our acute care surgeons are doing endovascular interventions in our operating rooms with a mobile C-ARM, a mobile bed and a single cart with a limited inventory.

Questions. How much of your course is on the failure modes of the technique? Like open surgery and flying airplanes, when everything goes well, it's easy and the difference between success and failure is dealing with the problems and complications of the technique.

Second, when the students finish the course do you recommend a preceptorship or a partnership with a vascular surgeon when they get home to learn to deal with these pitfalls?

These techniques are important. As trauma surgeons, we thought we cut for a living but what we really do is stop bleeding.

Dr. Randall Friese (Tucson, Arizona): What you presented here today is certainly designed for, as you brought up, the acutely hemorrhaging patient from intraabdominal sources.

But once we get used to these skills this seems to me the natural progression of this will be moving towards actual angioembolization in pelvic fractures and things like that.

I think these endovascular skills and using this as a stepping stone to achieve those is very, very important. And I hope to hear that you agree.

Dr. Carole Y. Villamaria (San Antonio, Texas): Thank you for those questions. I will go ahead and address Dr. Shackford's question.

As far as selection and participants, some were random and some actually contacted us with a desire to come. There was no payment for this course. This course was solely funded by a DoD grant through the Air Force.

As far as experience level of the participants, they were variable. However, they were all trauma surgeons. It varied from junior faculty to senior faculty trauma surgeons.

We actually had two fellows. One of them was an acute care surgery fellow and one was a vascular fellow who had actually already completed a trauma fellowship.

So is it worth training surgeons to use these endovascular skills? So a recent CRASH 2 trial showed that 5 percent of patients had bleeding as a cause of death which were potentially preventable.

And with this, we see that this is an area where we can potentially save lives. So, yes, we would like to train trauma surgeons these endovascular skills.

And as far as REBOA versus a conventional resuscitative thoracotomy, REBOA, like resuscitative thoracotomy, does increase central perfusion pressures; however, in a recent animal study that our group performed we show that there is less physiologic disturbance than with a thoracotomy in that you have decreased acidosis, decreased serum lactate, decreased PCO₂ and decreased fluid and pressor requirements.

Additionally, REBOA is less invasive compared to resuscitative thoracotomy. And also in resuscitative thoracotomy there is that challenge posed by clamp on and off as opposed to with REBOA you just simply inflate or deflate the balloon.

Also, just as a side note, multiple course participants have actually recently published their experience with REBOA after having gone through this course, confirming that the ability to learn this technique can be done very quickly.

As far as competing with IR and vascular surgeons for these skills, the most important endovascular skill for the acute care surgeon is to learn REBOA.

At institutions where IR is not readily available, the acute care surgeon may want to consider expanding their endovascular skills. However, we believe that we should partner with vascular and IR in performing procedures and not compete with them.

And, lastly, Dr. Shackford's question was do we need to each REBOA and in terms of inventory and imaging capability. So the inventory for REBOA is actually very minimal.

You just need arterial access, which everyone has in their trauma bay. You need a wire, sheaths and a balloon. And this could actually be packed in a little kit and so very, very minimal inventory.

And as far as imaging capability, all you would need - you could use a C-ARM. However, if you don't have that you can just use digital radiography and that is adequate. Okay?

And as far as Dr. Wall's questions, how much is the course focused on failure mode? And so like what I had explained earlier, the most basic part of endovascular skills is actually getting arterial access.

We noticed that some of our students were not able to get ultrasound-guided access initially and after actually three attempts we had the students go ahead and do a cut down. And so that was part of our failure mode.

In terms of partnership with vascular surgeon once done, we go ahead and basically encourage our students to get with their IR department, get with your vascular department and try to do this at your program.

However, as I had mentioned earlier, though, a lot of our students who finish this program go to their home institution and implement the skills that they learned from this course.

And as far as Dr. Friese, yes, I agree with you, sir. This is something that we need to do.